Hog Mortality Composting

Colorado
Governor's Office of Energy Management and Conservation

Revision 1 April 2003

TABLE OF CONTENTS

Preface
This manual reflects the findings of two pilot projects involving on-site composting of hog mortalities and birth-related tissues. Both projects were sponsored by the Governor's Office of Energy Management and Conservation (OEMC). The two projects developed methods, equipment, testing procedures, and safety protocols for hog composting. They also demonstrated the technical, economic, and environmental feasibility of this practice. Finally, the two pilot projects provided opportunities to introduce Colorado's hog farmers to composting and raise awareness of this option for disposal of carcasses.

The OEMC commissioned two pilot projects with the Northeast Colorado Health Department, and the cooperation of Alliance Farms and Central Plains Farms. The goals of the two pilot projects were:

1. Determine the technical and economic feasibility of on-site composting of mortalities and birth-related tissues at hog farms
2. Determine if on-site composting is a practical, energy efficient, and environmentally beneficial alternative to traditional disposal options such as rendering, landfilling, and burial
3. Gather data and documentation for the development of a "How To" manual on hog composting
4. Measure the quantities and types of energy conserved or offset
5. Measure the amount of material diverted from landfills
6. Demonstrate technology transfer and the ability for replication to other sites within Colorado
7. Demonstrate that on-site composting complies with state, local, and federal health, environmental, and composting regulations

The results of both projects are incorporated into this manual where applicable. All of the results are available through the OEMC office.

This is the second printing of this manual. A section on the use of a vertical grinder-mixer in mortality composting has been added to keep readers informed on new and developing practices in mortality composting.

INTRODUCTION: Why Compost?
Farmers have been composting agricultural crop wastes for many centuries. Stalks, roots, leaves, and other wastes are placed in large piles, where they decompose through the natural interaction between air, water, soil, and bacteria. The end product is an earthy, nutrient-rich material that can be applied to the next cycle of crops as fertilizer.

Using these same principles, hog farmers can dispose of dead hogs, birth tissues, and other organic waste materials in a clean, energy-efficient manner while, perhaps, improving their bottom line. Hog farmers in several states, including Colorado, have shown that composting can be an effective way to dispose of dead animals while gaining tangible benefits. These include:

- <u>Reduced costs?</u> While composting eliminates fees associated with rendering, hauling, and landfill deposits, other costs are required. These additional costs have not been definitively addressed in this study. However, if traditional rendering becomes more problematic and less available it may also become cost prohibitive. This study does suggest that composting is a feasible way of dealing with animal mortalities. Compared to other methods, it demands far less resources in terms of equipment, energy, land, and labor, and when assigning computed values to crop amendments, reductions in pollution and other variables, such as transportation, then a better understanding of cost offsets will be known.
- <u>Positive environmental impact.</u> Whereas burial, incineration, and rendering carry the threat of environmental damage, composting has a positive environmental impact: It reduces the amount of solid waste dumped into landfills, yields no air or water pollution, and requires no chemical additives. It utilizes and reinforces natural ecological processes.
- <u>Useful soil amendment.</u> The end product of composting is a nutrient-rich material that can be applied to crops as fertilizer, reducing costs in another area of farm operations, or can be commercially sold for numerous applications. Any reduction in use of petroleum-based fertilizers also means reductions in imported oil. Anecdotally, some dairy farms have found that they can make more money selling compost than from selling their dairy products.

Many of the procedures in hog composting have been developed in the Midwest and the Southeast, whose weather and climate are quite different from the conditions in Colorado. However, the same methods used in those regions have proven successful in Colorado. Given the right ingredients — moisture, air, bacteria, and a carbon-based bulking agent — hog composting can be conducted very effectively in Colorado’s climate.

■ How to use this manual

This manual presents a step-by-step approach to hog composting. It is based on actual data collected from swine operations in Colorado. The procedures discussed here have already been implemented successfully to produce high-quality compost, using materials readily available on Colorado hog farms.

The manual is divided into the following sections:

1. Overview of the Composting Operation
2. Constructing the Composting Bins
3. Filling the Bins
4. Monitoring the Compost
5. Troubleshooting
6. Addendum A - Use of a Vertical Grinder-Mixer in Mortality Composting

Successful composting requires farmers to follow proper procedures, use good and adequate equipment, and monitor their operations faithfully. If done correctly, composting can be a cost-efficient, energy-efficient, energy conserving and an environmentally sustainable method of hog carcass disposal.

1. Overview of the Composting Operation

Before beginning a composting operation, a hog farmer should evaluate his operation to ensure that the farm can support the venture adequately. It's necessary to know how many hogs die on the farm each week, how much birth tissue the hogs produce, and how much the carcasses and birth matter weigh. The farmer should make sure he or she has all the necessary equipment or acquires anything not already owned. Also, an appropriate site for the composting operation must be found and set aside. All of these factors should be taken into consideration before the composting process is set up.

This section will cover

- the composting timeline
- the ingredients of compost
- equipment
- site requirements
- regulatory requirements

A. THE COMPOSTING TIMELINE

Hog composting takes four to six months from start to finish, that is, from the time the first dead hog is placed in the bin to the time the compost is ready to be cycled back into the soil. The process is divided into two major segments, Phases 1 and 2.

■ **Phase 1**

In Phase 1, hog carcasses are placed in compost bins and combined, in alternating layers, with a carbon-based bulking agent such as straw, sawdust, woodchips, ground wood, or dead leaves to mention a few. Water is added, and the mixture remains in place for approximately 12 weeks. During this phase, soft tissue breaks down completely, while bones soften and undergo partial decomposition. The compost must be monitored regularly to ensure that the process occurs properly.

■ **Phase 2**

When the Phase 1 period ends, the compost is transferred to a separate set of bins for Phase 2. The purpose of this transfer is to aerate the material and to allow for water addition, if necessary. During this phase, which lasts for another 8 to 12 weeks, the bones decompose fully, and the compost acquires a musty odor.

At the end of Phase 2, the compost is finished and can be removed from the bins and applied directly to crops, or stored away for future use or sold.

B. THE INGREDIENTS OF COMPOST

Composting is the recycling of nitrogenous organic matter with other organic matter into a humus-like material by aerobic bacteria. Bacteria work as recyclers using a ***feedstock*** (“wet” nitrogen source - low C:N) in the presence of air, water, and a ***bulking agent*** (“dry” organic carbon source - high C:N). Examples of feedstocks (also called wet or green materials) are: mortalities, manure, septage, biosolids, fresh cut green grass, and ground green waste. Examples of bulking agents (also called dry or brown materials) are: straw, weeds, wood shavings, wood chips, and ground brown waste. Achieving the proper C:N ratio (C:N ratio is the carbon divided by the nitrogen and should be in the range of 20 to 30 parts carbon to 1 part nitrogen), material sizing, and mixing with moisture and air are critical to the composting process.

■ Hog carcasses

According to veterinarian Jerome Geiger, an expert on hog health, the nationwide average mortality rate for sows is 12 to 14 percent annually. For post-weaning hogs (nurseries and finishers), mortality averages 5 percent per year — 2 percent for nurseries and 3 percent for finishers. Geiger also reports that sow carcasses range from 300 to 600 pounds, with an average weight of 400 pounds. Pre-weaning mortalities average 4 to 5 pounds, while nurseries average 20 to 30 pounds (the range is from 12 to 65 pounds). Dead finisher hogs weigh from 65 to 290 pounds, with an average weight of 160.

Geiger’s numbers are nationwide averages, and they can be used to derive a rough estimate of mortality rate and weight for any hog operation. However, for best results a farmer should use specific figures for his own operation.

■ Bulking agent

Bulking agent is a critical factor in successful composting. In fact, it makes up the majority of the material in the compost bin about 1.5 to four pounds of bulking agent for each pound of hog carcass (depending on the bulking agent’s density and particle size). As an example, if the mortality rate was 6,000 pounds per week, it would be necessary to have available 9,000 to 24,000 pounds per week of bulking agent. However, some research has shown that bulking agent can be reduced by up to 6 times when a vertical grinder-mixer is used to prepare the carcasses (see Addendum A)

As mentioned above many materials can be used as bulking agent. When selecting the bulking agent, ensure that the material will be available in sufficient quantity, on an ongoing basis, in close enough proximity to the farm to make the process economical and to keep transportation to a minimum.

For a more detailed discussion of specific bulking agents, see Section 3, “Filling the Bins.”

■ Moisture and Air

Water is the lifeblood of the bacteria. Nutrients have to be dissolved into the water/air pore space before they can be assimilated by the bacteria. Bacteria also produce powerful enzymes to aid in material decomposition and digestion which occur in the liquid phase of the mix. Moisture can be added in various forms, including water, slurry, effluent, or pit waste.

Air, or more specifically oxygen, is required by bacteria for aerobic decomposition (composting). The bacteria use the oxygen from air trapped in the compost mix pore spaces and the carbon from the bulking agent to produce carbon dioxide (respiration). Air space (pore space) is provided by the structure or size of the bulking agent used. For specific discussion of the amount of moisture to add and material structure of each bin, see Section 3, "Filling the Bins."

C. EQUIPMENT

Hog composting does not demand an extensive range of equipment. However, without the proper machinery, a hog composting operation will most likely fail. Equipment needs and sizing are based on the size of the operation and the number of "deads" generated. At a minimum, an effective operation requires the following equipment:

- a loader to construct and fill bins
- machinery to process the bulking agent used in composting: if it's not pre-processed and delivered to the site
- a transport vehicle to bring dead hogs to the compost bins
- a water tank and pump
- a manure truck to haul manure to the bins and to field-apply the compost, if permitted
- basic monitoring equipment (see Section 4, "Monitoring the Compost")
- a log book to track bin status and test results

Since the original publication of this manual, research has been performed on mechanical carcass preparation and material mixing procedures using a dairy-type vertical grinder-mixer. Although not necessary for mortality composting it has been shown to reduce bulking agent and labor costs considerably (see Addendum A).

One of the two Colorado pilot projects sponsored by the OEMC used the following equipment to compost successfully on a 12,000 sow farrow-to-finish hog farm:

- Caterpillar 950 loader with a four-yard bucket. For most operations, a 1¼- to three-yard bucket on a skid loader, backhoe, or tractor will be adequate.
- Hesston 26 bale processor to grind baled cornstalks, hay, straw, and grass, which were used as the bulking agent.
- Two trucks fitted with "Tommy Lifts" to transport the carcasses from the production area to the composting site. The carcasses were sorted by size before being transported, a more efficient method than sorting at the composting site.
- A truck fitted with a 3,000-gallon water tank and high-volume pump (large enough to fill a fire hose). Because of the high volume of water required, a high-volume pump and hose were found to save time, money, and effort.
- A side-discharge manure truck. A honey wagon with a pump also may be used to add effluent or pit waste.

The demonstration farm used additional equipment to monitor the compost; see Section 4, "Monitoring the Compost," for further discussion.

D. SITE SELECTION AND PREPARATION

In selecting a site for the composting operation, the primary considerations are size, access, drainage, and health and aesthetic factors. A proper composting site should do all of the following:

- protect water quality
- prevent complaints and nuisance problems
- maintain bio-security
- deter varmints, vermin and vectors
- maximize efficiency

■ Size

How much acreage does the composting site need? That depends on the size of the hog operation and the number of hog carcasses it produces, which in turn determines how many composting bins will be needed and how much bulking agent will be required. The site must be large enough to house not only the composting bins but also a staging area for carcasses and bulking agent. Equipment clearance and transit must also be taken into consideration.

In pilot projects conducted in Colorado, a 12,000 sow farrow-to-finish operation required a minimum of one fifth of an acre for composting. For a more detailed discussion of how to estimate the correct number and size of bins, see section E below.

■ Water Quality

Nitrates are produced during the composting process. Nitrates may pose water-quality problems if allowed to leach into the soil. Composting facilities should be located away from streams, lakes, and wells to minimize the risk that runoff will enter these water bodies.

Floodplains should be avoided as much as possible. The composting site should be located on high ground. If facilities must be located in areas subject to flooding, they must be protected from a 25-year, 24-hour rainfall. Check with your local Soil and Water Conservation District or the Natural Resources Conservation Service to determine the rainfall corresponding to this storm level.

To protect groundwater, the composting facility should have a solid compacted pad, and must lay a minimum of three feet above the high water table. A 12-inch minimum base layer of the densest bulking agent is also mandatory for each bin constructed to work as a barrier between the carcass compost and the pad. These requirements help prevent water from leaching through the composting pad into the ground water.

■ Public Perception

Composting will generate little if any odor, flies, or other nuisances when managed properly. However, when siting the composting facility, neighboring residences, production facilities, and public roads and highways must be taken into consideration. Composting facilities should be located downwind of nearby residences to prevent any potential odors or dust from being carried to neighboring residences by prevailing winds. Aesthetics do matter; handling of dead swine may not be a welcome sight to nearby residents or passersby. Consider their line of sight when siting the facility.

■ Bio-security

Control of pathogens and disease is a critical issue for any hog operation. Traffic between the composting facilities and production housing should be minimized or, if possible, eliminated. The composting process destroys diseases, but bacteria and viruses from fresh mortalities can be passed through the transport vehicle to production housing. As noted above, runoff should be directed away from production facilities.

■ Varmints, vermin and vectors

Scavenging animals and vermin must also be kept from the compost. Maintaining the recommended cover over the compost pile will eliminate these problems (see Section 3, "Phase 1 Composting," for more information on capping). If scavengers such as coyotes know there are carcasses in the pile, they may dig in the pile to find them. However, proper bin management (no exposed carcass material, good overlying cover, etc.) has been shown to stop coyotes even when they may know that pigs are in a bin. Fencing may have to be installed if scavenging animals remain a problem. Vectors, such as insects and mites, if attracted to the pile because of improper composting procedures, can transmit diseases to other organisms.

■ Efficiency

Depending on the size and management of the hog operation, hogs may be added to the pile every day or several times a week. To avoid having water and mud interfere with access to the composting area, construct a roadway that provides all-weather access to the compost area. Loading and unloading at the compost facility must be possible in all conditions. Areas used to unload finished compost must be well drained and have a solid base, such as gravel or concrete. Traffic flow to and from the compost area must be taken into account. Appropriate distances from overhead and underground utilities must be maintained to insure safety. The composting facility should be located and constructed so as not to interfere with other farm operations.

■ Site Selection Checklist

The Natural Resources Conservation Service recommends that hog farmers use the following checklist when selecting a site for composting facilities:

Is the site

- Away from ponding areas or drainage patterns (high and dry)?
- At least 300 feet from streams, lakes, waterways, etc.?

Does the location provide

- Suitable access to storage for bulking agent?
- Clearance from underground and overhead utilities?
- Minimal interference with other farm traffic?
- Sufficient square footage for your volume of carcasses?

Does the site have

- Runoff collection and available treatment areas?
- All-weather access to the compost area?
- All-weather compost pad?

Has the producer considered

- View from neighboring residences?

- Prevailing winds for the site?
- Bio-security precautions?
- Aesthetics and landscaping?

E. REGULATORY REQUIREMENTS

When beginning a composting operation all hog farmers should become familiar with Colorado environmental regulations. Check with the local health department or the Colorado Department of Public Health and Environment to determine which regulations may apply. **(303) 692-3500.**

2. Constructing the Composting Bins

Hog composting requires two separate sets of bins — one for Phase 1, another for Phase 2. Building the right number of bins, and building them to the right size, is crucial to success. It is also very important to use the right construction materials and design specifications. The composting bin facility should be built to handle all mortalities on a continuous basis throughout the entire year.

This section will cover

- Materials and layout
- Number and size of bins

A. MATERIALS AND LAYOUT

Composting bins have been constructed utilizing a number of materials, including wood, concrete, tire bales (utilized effectively by the two farms in the OEMC demonstration effort), square and large round straw bales. Most compost bins are three-sided, and some are covered with a roof. Given Colorado's low precipitation totals, it is generally felt that roofing the bins is unnecessary. However, it is recommended that once the bin has been filled, one to two feet of uncut straw should be added to the top layer of the bin, slanting slightly from front to back, so that excess moisture runs off the bin. This is known as "capping" the bin. See Section 3, "Phase 1 Composting," for more information.

The bins must be built upon an impervious pad to prevent moisture from leaching out of the bins into groundwater. A concrete base may be used, but if it can be established that the surface is impervious because of clay soil or other material, then the concrete pad may not be necessary. A soil monitoring program may be required if pad permeability cannot be proven.

Any permanent walls that may come in contact with the compost should be constructed of rot-resistant materials. Walls constructed with hay bales will deteriorate eventually, but this is not problematic as they can be readily replaced. Rotting bales make a good bulking agent that can be added to the process, thereby creating a fully self-sustaining facility. Although many composting structures are built specifically for composting, it is often possible to adapt an existing building for use as a composting structure.

When determining the layout of the bins, prevailing winds and other weather conditions should be considered. For example, none of the bins should face a direction where prevailing winds can sweep dirt and other material into the bin or blow material out of the bin. Bins should face south for additional winter heat, if possible.

B. CAPACITY AND BIN SIZE

The number of composting bins required depends upon the mortality rate of the farm which is the average number of hogs that die each week, and the average aggregate weight of the mortalities. See the formula below. From there, it is possible to calculate how much bulking agent will be required, how much bin capacity will be needed to hold the compost, and how large a site it will take to house the whole operation. If there is an art to hog composting, it comes into play in bin sizing.

■ Phase 1 bins

Phase 1 bins are where all the ingredients — carcass, bulking agent, and water — are brought together for the first time. Because composting begins here, the Phase 1 bins are the central focus of the entire operation.

The University of Nebraska has an excellent bin-sizing spreadsheet online at
http://manure.unl.edu/composting.html.
Click on Mortality Disposal Options,
Click on Composting Sizing Spreadsheet,
Click on *composter-v1.xls* and download it; then input the hog farm's mortality figures to find out how many bins are required at what sizes, and how much bulking agent is needed. It is possible to adjust some of the formulas to allow for varying bin sizes and bulking agents.

Overall Capacity

For Phase 1, studies from the University of Minnesota recommend that composting operations provide 150 cubic feet of bin space for every 1,000 pounds of carcasses. This volume includes not only the carcasses but also includes the bulking agent and water used. As an example, a farm with a mortality rate of 12,000 pounds of carcasses per week would fill 1,800 cubic feet of bin space every week.

Each load of compost remains in its bin for 12 weeks during Phase 1, so it is necessary to provide 12 weeks' worth of capacity. Using the example above, a farm filling 1,800 cubic fit of bins space every week would multiply that number by 12, to arrive at a total of 21,600 cubic feet of Phase 1 bin capacity.

The formula for determining overall Phase 1 bin capacity is as follows:

mortality rate (pounds/week) x 0.15 (cubic feet / pound) x 12 (weeks in Phase 1)

As each bin reaches the end of the 12 week Phase 1 period, the material is removed and transferred to Phase 2 bins (see below). The emptied bin is then ready for the next loading, and the whole process starts over again.

Individual Bin Size
As with overall capacity, proper composting bin size depends upon the mortality rate of the individual farm. Each Phase 1 bin should be constructed so that it fills up in one week. Using the example described above, a farm with 12,000 pounds of deads a week and requiring 1,800 cubic feet of bin space per week should construct Phase 1 bins of no larger than 1,800 cubic feet. However, It might be more effective to build bins of 900 square feet (15 x 10 x 6 feet) and fill two bins every week.

Bins that are too large require too much time to fill, leaving the carcasses exposed to flies, bad weather, and scavengers. The oversized bins also result in uneven composting; if it takes 14 days to fill a bin, the material on top is much less mature than the material on the bottom.

Bins that are too small may not allow enough room for bulking agent and water, leading to very poor results (including anaerobic rotting and odors). Undersized bins lack proper insulation, leaving them vulnerable to temperature swings that can interfere with the composting process.

In the two Colorado pilot projects sponsored by the OEMC, Phase 1 bins ranged from 1,536 cubic feet (12 x 16 x 8 feet) to 1,152 cubic feet (12 x 16 x 6). The bins accommodated between 6,000 and 9,300 pounds of hog carcasses, along with the corresponding volume of bulking agent.

- **Phase 2 bins**

After 12 weeks in the Phase 1 bins, compost is ready for transfer into the Phase 2 bins. The purpose of the transfer is to provide aeration and moisture which helps reestablish bacteria populations so the bin will reheat and increase decomposition efficiency.,

Overall Capacity
Most literature on hog composting recommends that overall Phase 2 bin capacity should be equivalent to Phase 1 bin capacity. However, the two Colorado pilot projects found that successful composting required only one Phase 2 bin for every two to three Phase 1 bins. The decomposition that occurs in Phase 1 shrinks the overall volume of the compost, so that by Phase 2, less bin capacity is required.

When combining the contents of several Phase 1 bins into a single Phase 2 bin, care must be taken to ensure that the material from the various bins is all on a decreasing temperature trend. Also, all of the bins' material should fall within approximately 10 degree Fahrenheit range. The bins' material should have similar color, odor, and the carcass material should be in the same or close to the same stage of decomposition. For Phase 2, it is best to combine Phase 1 bins that were filled within four weeks time of each other.

Individual Bin Size
As a general rule, Phase 2 bins should be the same size as Phase 1 bins.

3. Filling the Bins

When all siting and construction preparations listed above have been completed, the bin loading operation can begin. The carcasses are placed in the composting bins and combined with bulking agent and moisture. When the bin reaches full capacity, it is capped.

This section covers:

- preparing composting ingredients
- filling the Phase 1 bins
- filling the Phase 2 bins
- removing the finished compost

A. PREPARING INGREDIENTS OF COMPOST

■ Preparing carcasses

Dead hogs must be removed from the production area as soon as possible and transported to the composting site. Upon arrival, they should be loaded immediately into the composting bin. Hogs laid on the ground in hot weather will bloat, draw vermin and vectors, and exude powerful odors. Those laid on the cold ground in winter will freeze, inhibiting decomposition.

Before loading carcasses into the composting bin, trash, such as catheters, birthing gloves, syringes, etc., must be removed. Place each carcass into the bin stomach up. Large hogs (weighing 100 pounds or more) must then be splayed under each leg and from stem to stern. In this way you will expose the large animal's internal organs to the air, water, and bulking agent and speed the composting process. Note: See Addendum A for a discussion on using a vertical grinder-mixer for carcass preparation.

■ Preparing bulking agent

Bulking agent should be no more than three inches in diameter. Bin composting works best when the agent is sized below ¾ of an inch. The preparation required varies depending upon the type of material used.

- Sawdust needs no preparation. Sawdust from almost any woody source will do.
- Baled material — including hay, straw, weeds, grass, and cornstalks — can be reduced to size using a bale buster, hay grinder, or any other piece of chopping equipment. Cornstalks may have to be passed through two times to reach an acceptable size.
- Recycled wood from demolished buildings and tree cuttings should be ground to pieces with a maximum size of 1¼ inch.
- Chipped wood (< ¾ of an inch), dried grass clippings, and dried leaves can be used as is.
- A vertical grinder-mixer may also be used to grind straw, weeds, small twigs and brush, and weeds (see Addendum A for details).

For efficiency, it is important to have a good supply of bulking agent on hand at all times, and to restock the composting center well before supplies run low.


Layer 4 to 6" of Bulking Agent
(ground straw, hay, weeds, grass, or sawdust)


First Layer of <30lb Pigs and Afterbirth on a 16" Layer of Sawdust


Last of 7 Combined Layers (7 Days of <30lb pigs and Afterbirth)


Finishing Off the Bin With a Straw Cap

B. FILLING THE PHASE 1 BINS

When carcasses are loaded into Phase 1 bins, they are placed in layers of one to two feet, along with water and bulking agent. A six inch layer of bulking agent is sandwiched between each carcass layer. Prodigious layering ensures that interaction between the bacteria and the ingredients properly takes place, and helps maintain a proper balance of moisture, hog carcass, and bulking agent. Improper layering can lead to odors, uneven composting, scavenging, and oozing and subsequent leaching.

- Bottom layer

The bottom layer consists of bulking agent (the densest bulking agent available, sawdust or finely ground straw) that is simply dumped or blown into the bin and spread evenly from corner to corner. Pitchforks may come in handy when spreading the material. This layer should be at least one foot deep.

- Layers 1 through 3

When the first carcasses are added to the bin, record the date and bin number in the composting log book. The first layer of carcasses lies directly atop the bottom layer of bulking agent. For smaller carcasses (weighing less then 100 pounds) and afterbirth, little or no free space is required between animals and afterbirth can be placed atop the carcasses.

Free space (6 to 12 inches) is required between larger carcasses (weighing more than 100 pounds). As noted above, the larger animals must be splayed before being deposited in the bin, because their thick hides take longer for the bacteria to penetrate. Opening them up gives the bacteria a greater surface area on which to operate and makes the softer more readily compostable internal organs more accessible.

After the first layer is completed, the carcasses should be covered with bulking agent, and then water should be applied to achieve a moisture content of approximately 45%. See Section 4 "Monitoring the Compost Process", Section B "Testing for Moisture" page 18 for information on how to test for moisture content. In states other than Colorado, swine manure, pit waste, and/or effluent may also be applied. Do not add moisture to a partially completed layer, as this often leads to over watering, which can unbalance the mixture and impede decomposition. However, if a layer is only partially completed at the end of the day, bulking agent should be applied to minimize odors and deter scavenging animals. The next day the bulking agent can be raked aside, and the layer can be completed with new carcasses.

Build the second layer directly on top of the first one, following the same procedures. However, when the layer is completed and water is applied, the moisture content should be adjusted to 55 percent. The same steps are followed to construct layer 3, except the moisture content should be adjusted to approximately 60 or 65 percent. All subsequent layers should be between 65 and 70 percent moisture. See Section 4 "Monitoring the Compost Process", Section B "Testing for Moisture"

- Capping the bin

When the final carcass layer is in place and the bin is at full capacity, it is topped off with a sloping cap made up of uncut straw or other dense bulking agent.   Straw is preferable because it sheds water well but at the same time allows good air penetration. This top layer will shed most rains in Colorado. The cap should slope up from front to back, with bulking agent piled two feet deep at the north or back end of the bin and sloping down to six inches deep at the south or front end of the bin. Spray water over the cap, and then add more bulking agent and/or straw as needed; water again and repeat the steps until the cap is firmly in place. When the bin has been filled and capped, record the bin number and date in the composting logbook.

4. Monitoring the Composting Process.

C. FILLING THE PHASE 2 BINS

Approximately three months after the last hog has been placed into the bin and all of the water, manure, and bulking gent has been added, the bin contents will probably be ready to be moved from the Phase 1 bin to the Phase 2 bin. When the material is transferred, record the date and bin number in the composting log book.

The key indicator for moving the bin material will be bin temperature. Over time, temperatures will gradually decrease to a point where the temperature bottoms out and finally straight-lines. Bottomed out, straight-lined temperatures indicate that decomposition has stopped and the bacteria have used up the available nutrients; air, and moisture.

If the Phase 1 bin was properly prepared, the fleshy material will have decomposed by this time. Moisture will have been lost, and an addition of water will help Phase 2 proceed at a more efficient rate. However, too much water at this stage will impede the compost, so great care must be taken to avoid over watering. Humic matter produced to this point by the composting process will absorb and hold water, so less water is needed. Using a hose or a water truck, apply water until a 45 to 50 percent mixture is achieved while moving the material from the primary bin to the secondary bin with the bucket loader. Each bucket of material should be dumped into the secondary bin from the bucket loader's highest level in a cascading manner to break up clumps of material and to introduce as much air as possible.

After each bucket loader dump, take a one-liter sample of compost and place it into a one-cubic-foot bulk density box. Fill the box with compost and weigh it. Record the weight into a logbook. Using the microwave testing procedure or hand-squeeze moisture test described in Section 4 (“Monitoring the Compost”), measure the moisture percentage of the compost. Three separate bulk-density and moisture readings should be performed.
As noted in Section 2 (“Constructing the Compost Bins”), each Phase 2 bin may hold the contents of two to three Phase 1 bins. When the Phase 2 bin has been filled, finish it off with a fresh lean-to cap as described in Phase 1 above, on page 15.

Once the bin is capped, continue to monitor Phase 2 bins as you did Phase 1 bins for temperatures, odor, varmints, ooze, and flies see, Section 4. Monitoring the Composting Process.

D. REMOVAL AND USEAGE OF FINISHED COMPOST

Eventually, within 8 to 12 weeks bin temperatures will again drop off as they did in Phase 1 but this time they will not reheat when aerated. The starting materials will have been decomposed by bacteria into finished compost.

Finished compost should be dark brown to black, with an evenly dispersed particle size and a musty dirt-cellar or soil odor. No odor of ammonia or decaying meat should be present. If proper composting has occurred, the material will have shrunk by as much as three feet in a 12 x16 x 8 ft. bin.

Three testing procedures described in Section 4 ("Monitoring the Compost") can be used to confirm that the compost is finished. The microwave moisture test or hand-squeeze test should reveal a moisture content of 25 to 30 percent, the bulk density of the compost should be at its heaviest point, but most importantly, the bag odor test should leave the impression of a soil like odor. If an odor of rotten eggs, rancid meat, ammonia, or manure can be detected the material may have to be placed into a third bin, the moisture and bulking agent adjusted and the material allowed to further compost. See Section 4 for testing procedures and protocols.

If the finished compost is to be sold or used in other non-farming applications (landscaping, vegetable gardening, etc.) then the finished compost should be sampled and tested for fecal coliform or *Salmonella* at a laboratory certified for bacterial testing and has experience in analyzing compost. Call the Colorado Department of Health and Environment, Colorado State University, or your local health department for lab listings. Laboratory testing is also highly recommended if the compost has not reached and maintained pathogen destruction temperatures (>131 ^{0}F) for several weeks or if temperature data is unavailable.

Finished compost can be stored in any location. However, precautions should be taken in order to prevent the material from blowing. Sometimes, depending on the size and type of bulking agent and final moisture, particle composition may be so fine and dry that little wind is needed to scatter it. When the composting process is completed, record the date and bin number(s) in the composting log book.

According to Colorado Regulation No. 2, Part B, the finished compost product can be land applied year-round (as long as no manure or effluent has been added during the composting process) and does not require incorporation into the soil like land applied solid waste, separated solids or sludge. An operator should check with the Water Quality Control Division to verify land application regulatory requirements included in Water Quality Regulation No. 61, Section 61.13 prior to land application of compost. Specifically, item (31) of this regulation states that any housed commercial swine feeding operation "capable of housing 800,000 pounds or more of live animal weight of swine at any one time or is deemed a commercial operation under local zoning or land use regulations" and "have the capacity to house:

(a) 11,500 weaned swing (70 pounds or less), or
(b) 3,020 feeder swine (more than 70 pounds, up to finish weight), or
(c) 2,000 breeding sows and/or boars"

MUST have a permit to land apply any soil amendment containing swine manure.

4. Monitoring the Composting Process

Successful composting requires ongoing monitoring and testing to ensure that bacterial decomposition and material breakdown are occurring properly and at proper rates. The tests depend upon simple observation and common sense. The odor, feel, and look of the compost provide important information about the state of the composting process. Other information comes from simple measurement and analysis of temperature and density. These tests indicate when the compost is ready to be moved from Phase 1 bins into Phase 2 bins and then piled as finished compost.

This section covers:

- Equipment
- Testing for temperature
- Testing for moisture
- Testing for odor
- Testing for density

A. EQUIPMENT

All of the tests require physical handling of compost. The tester should always put on plastic or rubber gloves before handling unfinished compost to prevent infections or transport of disease-producing organisms. In addition, all test results should be recorded in the compost log-book.

Other testing equipment used in monitoring the compost process includes:

- a four-foot temperature probe
- a one-cubic-foot box made of ½-inch plywood, with a strap or wire hanger so the box can be weighed from a hanging scale
- a hanging scale
- a microwave oven
- an analytical balance calibrated to the nearest tenth of a gram

B. TESTING FOR MOISTURE

Moisture content is an excellent indicator of the state of your compost. During the initial filling of the bins, large amounts of moisture are pumped into the compost mixture. As decomposition proceeds, tissues break down and release more moisture. Initially, high temperatures cause material drying through moisture evaporation but, over time, the composting process produces humic matter which will absorb and hold added moisture.

There are two ways to measure the moisture content of your compost: the hand-squeeze test and the microwave oven test.

■ Hand-squeeze moisture estimate

This procedure requires no equipment other than a pair of gloves. It yields a rough estimate of the level of moisture in the compost.

Procedures:

1. Dig into the bin and retrieve a handful of compost material.
2. Squeeze the compost tightly several times to form it into a ball.
3. Assess
   a. whether the ball cohered or crumbled
   b. if it crumbled, whether it broke into halves, thirds, quarters, or smaller fragments
   c. whether the ball stayed intact after being gently bounced three or four times in the palm of your hand
   d. whether water oozed from the material
   e. if water oozed, whether it was slimy and foul-smelling or wet with a musty soil-like odor
4. Repeat the procedure at least four different times from four different areas of the composting bin (see Assessment below for Hand Squeeze moisture test results).

Assessment:
In Phase 1, the compost should ooze just a few drops of water and leave no visible trace of moisture. The ball should easily withstand three bounces without crumbling. If the ball crumbles, the compost is too dry and moisture needs to be added. The water can be injected down into the pile, past the cap. If the ball cracks into big pieces but does not crumble, there is almost enough moisture; you can add a small amount of water immediately, or wait to see if the compost becomes crumbly as temperatures increase. If the material is wringing wet, then more bulking agent needs to be added, and the bin may need to be aerated sooner than expected.

In Phase 2, the material should be crumbly or chunky after a squeeze test. The material should hold a ball shape for at least two bounces.

■ Microwave oven moisture test

This test requires an ordinary microwave oven, an analytical balance capable of measuring weights to the nearest tenth of a gram, and a notebook. The object is to determine what percentage of moisture the compost contains.

Procedures:

1. Measure 100 grams of well-mixed compost onto a clean paper plate.
2. Place the sample into the microwave. Take care not to spill any of the material, as this will distort the results of the test.
3. Cook the sample on high for three minutes.
4. Remove the sample and let it cool for two to three minutes.
5. Weigh the sample and record the weight in the notebook.
6. Place the sample back into the microwave, cook on high for two more minutes, cool, weigh, and record the weight in the notebook.
7. Place the sample back into the microwave, cook on high for one more minute, cool, weigh, and record the weight in the notebook.
8. Repeat step 7 until the weight stays the same for three consecutive weighing cycles.

9. Subtract the final weight from 100; the difference is the moisture percentage of the sample. For example, if the final weight is 65, then the moisture content is 35 percent (100 – 65 = 35).
10. NOTE: If you detect a burning odor or the sample catches fire, start the entire process over, with reduced cooking times. Burning will yield inaccurate results.

Assessment:
In Phase 1, the compost should have a moisture content of 55 to 65 percent. If the moisture content is below 55 percent, water must be added as described above; if the moisture content is above 65 percent, add bulking agent.

During Phase 2, moisture content should measure from 45 to 55 percent. If the moisture content is low and more water is needed, it should be added very slowly. Over watering at this point will inhibit the final stages of the composting. If the composting process is proceeding as planned, the compost should be allowed to dry (gradually) to a moisture content of approximately 30 percent. 30 percent moisture is ideal for finished compost.

C. TESTING FOR TEMPERATURE

The breakdown of hog tissues and bulking agent releases heat. Temperature measurements indicate whether matter is breaking down at the proper rate.

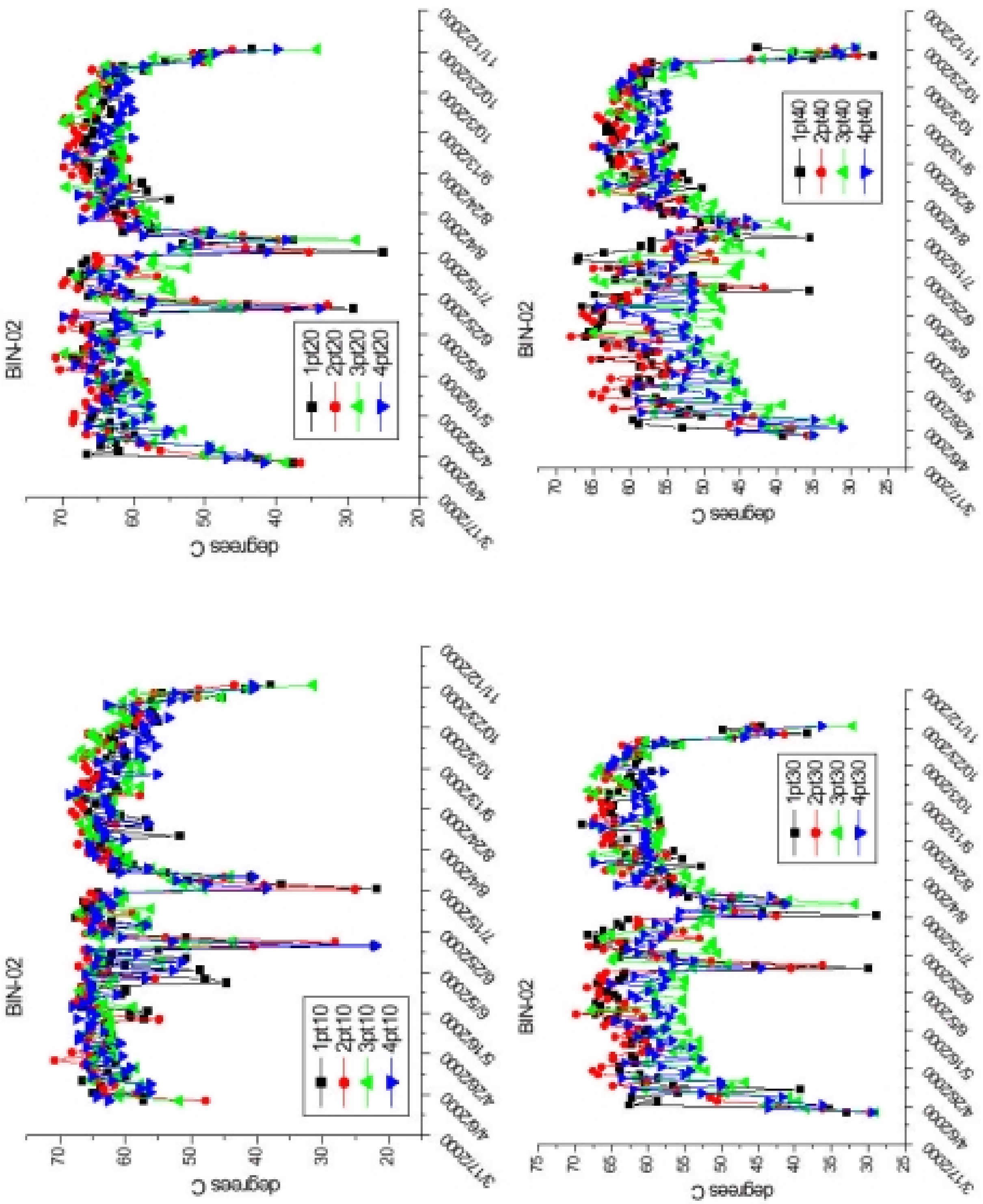
The test requires a four-foot probe fitted with one or more thermisters. The object is to measure the temperature at 10-, 20-, 30-, and 40-inch depths at 4 random points in the bin. The best information comes from a probe fitted with four thermisters, one each at 10, 20, 30 and 40 inches. A four-foot probe with a single sensor can be used, with the sensor pushed from one depth to the next. However, this slows the process, because the tester must allow time for the temperature to stabilize separately at each depth.

Procedures:
1. Enter the bin number, date, time, and ambient temperature in a temperature log.
2. Connect the temperature recorder to the probe, and compare each channel to another temperature measurement device to ensure proper functionality of the recorder and probe.
3. Divide the bin into four quadrants. It's best to randomly test different points within each quadrant each day.
4. At point No. 1, carefully insert the probe, straight down, all the way to the 40-inch mark. Do not push on the electrical connection at the top of the probe.
5. Switch to the 40-inch channel, and let the device stabilize. Record the temperatures in the compost temperature log.
6. Carefully remove the probe by pulling on the steel section of the probe and by pulling as straight as you can from the insertion hole. Pulling at an angle to the hole will bend the probe, and pulling on the probe handle will break the thermister connections.
7. Repeat steps 4 through 6 for the second, third, and fourth quadrants.
8. Repeat all steps above for each bin at least once a week.

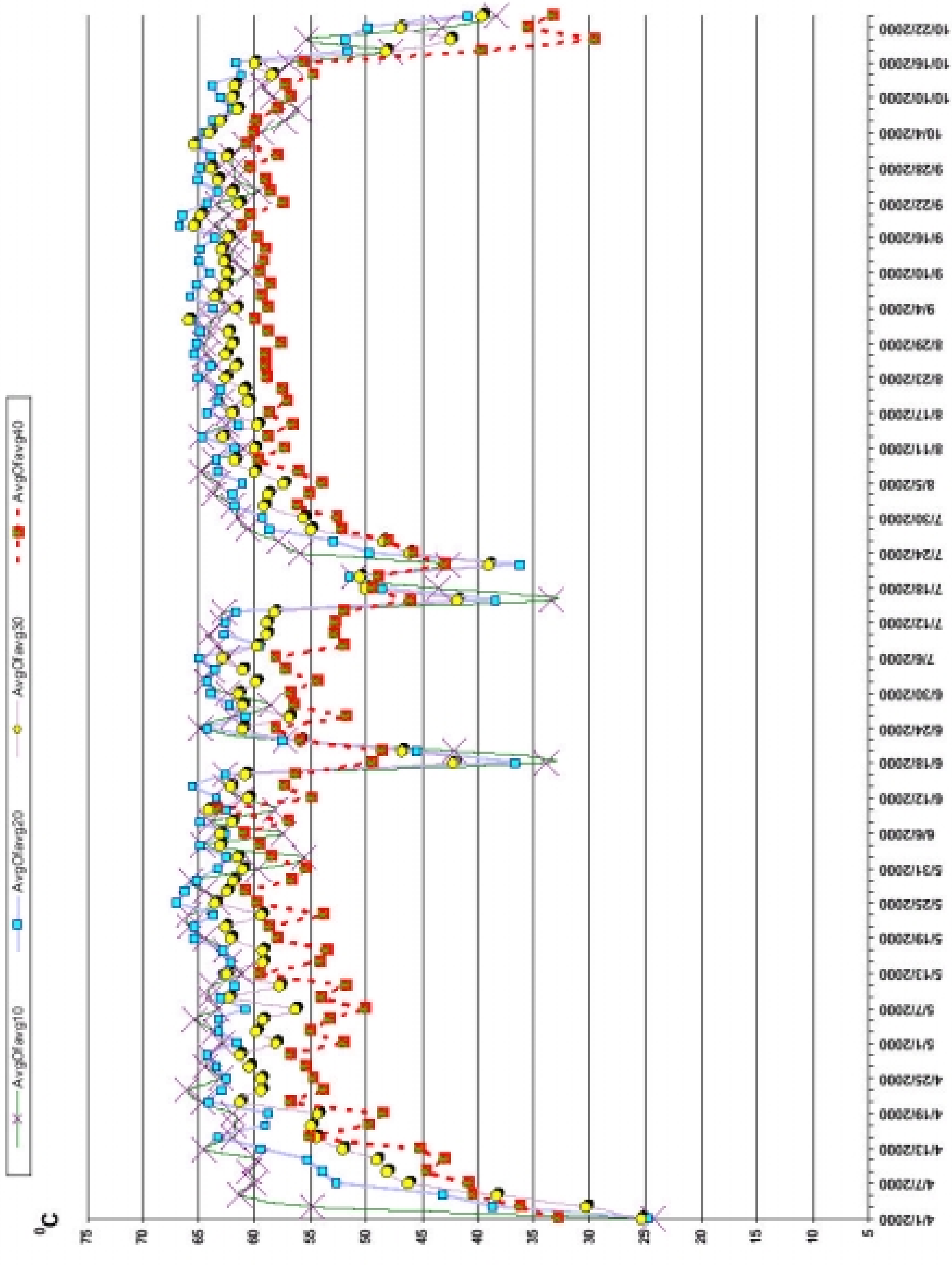
Assessment:
In a properly constructed bin, compost should start increasing in temperature within one week. The temperature at the core should rise to at least 130 to 140 degrees Fahrenheit within 10 days and stay there for several weeks. Temperatures will be slightly lower near the top of the bin (the 10 inches directly under the cap); however, if the average temperatures at the top are 10 to 20 degrees lower than the inside temperatures, and stay that way for more than two weeks, then the inside has too much moisture and should be aerated. The squeeze test and odor test (see below) can be used to confirm this conclusion.

In Phase 2, temperatures fall as the easily consumed carbon is digested. When the temperature stabilizes at ambient levels (circa five to six months), this is a good indication that the composting process is complete.

Bin Temperature Graphs
Typical bin temperature at 10" Graph 1, 20" Graph 2, 30" Graph 3, and 40" Graph 4 are shown below. Valleys indicate water additions and then aeration (compost moved from Phase 1 bin to Phase 2 bin). The averages for these four depths across time are shown in Graph 5.
An example of a Swine Mortality Compost Bin Temperature Monitoring Sheet is located on page 25.



Graphs 1-4. Typical bin temperatures at various depths across time.



Graph 5. Average bin temperatures for four different depths, across time.

Table 1.

Compost Bin Temperature Monitoring Sheet											
BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")	BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				
BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")	BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				
BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")	BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				
BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")	BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				
BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")	BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				
BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")	BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				
BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")	BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				
BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")	BIN#:	Point	ch-1 (10")	CH-2 (20")	Ch-3 (30")	Ch-4 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				
BIN#:	Point	ch-4 (10")	CH-3 (20")	Ch-2 (30")	Ch-1 (40")	BIN#:	Point	ch-4 (10")	CH-3 (20")	Ch-2 (30")	Ch-1 (40")
	1						1				
Date:	2					Date:	2				
Time:	3					Time:	3				
Air Tmp.:	4					Air Tmp.:	4				

D. TESTING FOR ODOR

Under proper conditions and with a proper mixture of ingredients, compost should not produce foul odors. If the C:N ratio is "in balance", then the presence of odors indicates that the air and water mixture is out of balance. Otherwise, bad odors are caused by an improper C:N ratio, usually too much feedstock to bulking agent (a low C:N ratio).

This test requires no equipment other than gloves and a Ziploc bag. It yields a subjective assessment of the compost odor and should be performed at least once every quarter. Follow these steps:

Procedures:

The bag odor test is performed as follows:

1. Place a couple of handfuls of compost to be analyzed into a 1-gallon plastic snap seal type bag.
2. Zip the bag closed and let it set for an hour or place the sealed bag in the sun for 5 to 10 minutes.
3. Open the bag and immediately take a whiff from the opening. *Caution: You may experience a very strong unpleasant odor indicating the composting process is not fully done, even though it may look finished.*
4. Answer the following questions:
    a. Was there a rotting flesh odor?
        i.) If so was it overpowering or faint ?
    b. Was the odor reminiscent of manure ?
    c. Was there a strong ammonia odor but less of a manure odor ?
        If the answer to any of the above is yes, you have incomplete compost, which is OK at the end of Phase 1 but requires corrective action at Phase 2.
    d. Was there a sweetish, slightly burning cookies-type odor ?
        If yes, then the compost is almost complete but needs a couple more weeks to finish up.
    e. Was the odor a musty soil odor like that of a dirt cellar?
        If yes, you have complete compost.
5. Repeat this procedure on a minimum of four different samples.
6. Close the plastic bag and place in the sun or a warm place for a couple of hours. Re-open the bag and take a whiff, compare it to your earlier observation from the same bag.

Assessment:

Odor is produced when the composting process has become unbalanced with regards to the air, moisture, carbon, and nitrogen mix. At the beginning of Phase 2, the compost should have a strong ammonia odor and may have a very slight hint of rotting meat. Finished compost has no ammonia odor or rotting-meat odor. Sour, rank odors (rotten egg to rancid carcass odors) are usually an indication of anaerobic conditions brought about by too much water and/or flesh (feedstock) and not enough air and/or bulking agent. If these odors are encountered, corrective actions must be taken (see Corrective Action in Section 5. Troubleshooting). If you notice the odors described in sections a., b. or c. above, at the scheduled end of the process, you are not at the end of the process. Be prepared to go into a Phase 3 which is the "re-binning" of Phase 2 compost with water, bulking agent, and more time.

D. TESTING FOR DENSITY AND TEXTURE

■ Bulk density

The bulk density is a measure of mass per volume. When measured regularly for all bins, it's a good indicator of how each bin's material has composted. Run this test in conjunction with all of the other tests especially the moisture test. This test requires a one-cubic-foot box, a hanging scale, and a Swine Mortality Bulk Density Analysis Log Sheet located at the end of this manual page 31. It should be conducted at least twice: once when the compost is moved from the Phase 1 bin to the Phase 2 bin, and once when it is moved out of the Phase 2 bin.

Procedures:

1. Attach a one-cubic-foot box to a hanging scale, tare the scale and then remove the box from the scale.
2. Place random handful samples of compost into the box. Do not pack the material; loosely fill it so that the material maintains the same structure as the bin you are sampling. The box should be full by the time you have removed one-fourth of the bin's contents.
3. Scrape off any excess material so that the top of the compost is level with the top of the box.
4. Attach the box to the pre-tared scale and record the weight in the Bulk Density Analysis Log Sheet
5. The weight divided by the volume equals the bulk density.
6. Follow steps 1 through 5 for each bin.

Assessment:

In general, bulk density is lower at the beginning of the process than at the end. At the time the compost is transferred out of the Phase 1 bin, bulk density should be from 20 to 35 pounds per cubic yard. At the end of Phase 2, bulk density should rise to between 40 and 50 pounds per cubic yard.

■ Particle Size/Color

This test requires no equipment other than gloves. It can be done concurrently with either the hand-squeeze moisture test or the odor test. The objective is simply to gauge the compost visually.

Procedures:

1. Gather a small sample of compost from the bin. If desired, use the same sample taken during either the odor test or hand-squeeze moisture test.
2. Inspect the compost visually and assess
    a. the color of the material (black, brown, dark brown, gray, etc.)
    b. whether the color is consistent throughout the bin, or whether there are darker or lighter areas
    c. whether the color resembles the color of other composts that have been made on site
    d. whether there is a white layer of bacteria under the surface of the bin cap.
    e. if there is a bacterial layer, how thick and how deep below the surface it is.
    f. whether the starting materials are still distinguishable and, if so, whether they

have degraded in size and changed color.

g. whether there are large clumps, small clumps, or small hard balls in the bin.

h. whether the texture is grainy and evenly distributed, or fibrous, lumpy, and muddy.

3. Repeat with samples from at least four different places in the bin.

Indications:
At the start of Phase 1, bin particle sizes tend to be widely variable due to the differences in size and character among the starting ingredients. Over time the particles should become smaller and more uniform in size, and the color should become a uniform dark brown to black.

5. Troubleshooting

Many factors can affect the success or failure of a composting operation. Experience has shown that adjustments and fine-tuning are always required to keep the operation on track. This section covers common problems in hog composting, along with common sense responses for each situation.

■ **Compost does not rise to expected temperatures**
Within a week or two after a composting bin is capped, the temperature should rise to 130 degrees Fahrenheit or higher. The temperature rise results from the activity of bacteria as they compost the bin materials. If this temperature increase fails to occur, it means the bacteria are not active enough, or that there are not enough bacteria present.

Solution: One method would be to determine if the bin is composed of the proper mixtures of bulking agent and mortalities or if the bin is too wet thus starving the bacteria of air or too dry, thereby leaving the bacteria without the necessary moisture to consume the compost materials. Check to see if the bin temperature is cooler in the bin's core than the outside layers. Cooler cores indicate a wet bin. A warm core compared to the outside layers indicates a dry bin. Check the bin record and determine if the bin's C:N ratio has been correctly determined and is between 20 and 30. If it is not, reload the bin properly. Finally, use a shovel or bucket loader and dig into the bin several feet. Check the moisture using the hand-squeeze moisture test. If the bin material is too wet and it has a foul odor follow the Bin Corrective Action procedure while adding bulking agent to achieve the correct moisture.

Another method would be to add cattle feedlot, chicken, or horse manure to the compost bin (check with the Colorado Department of Public Health and Environment prior to adding swine manure to a bin). Manure is rich in nutrients needed by the bacteria to consume the materials in the composting bin. Nitrogen rich substrates, such as manure, can jump-start the bin and get bacterial activity going. If the initial bin loading recipe was right, then the temperature should increase within a week or two after manure is added, indicating that the composting process has begun.

In the winter ensure that hog carcasses, bulking agent, and other ingredients of the composting bin are protected from the winter elements prior to loading the bin. Carcasses should be stored in a barn, shed, or other covered space to protect them from freezing temperatures if they cannot be immediately loaded into the bin. Frozen pigs will not compost until thawed. Bulking agents and other compost ingredients should also be kept dry so they do not matt or freeze into unusable clumps.

- **The bins are leaching excessive amounts of moisture.**

Moisture is an important ingredient in composting, but it must be contained within the bins. If composting effluent oozes from the bins, it could leach into the soil, attract animals and insects, and present an odor problem. Effluent oozing is caused by too much moisture in the bin either from too much water added during bin layering or from excessive rain soaking into the bin.

Solutions: If it has rained within a couple of days of the initial oozing the chances are the effluent may be puddling around the perimeter of the bin and that the bin contents are not too wet. Check your bin temperatures. If the inside temperature (3 to 4 feet) of material in the bin is from 20 to 30 degrees cooler than the outside 1 foot than there is a possibility the bin is soaked. Use a shovel or bucket loader to dig into the bin 2 to 3 feet. Use the hand squeeze moisture test to determine whether the compost material is too wet. Use the Bin Corrective Action (see below) procedure to move the composting material to another bin while adding bulking agent to achieve the proper moisture content. If it has not rained during bin oozing, the chances are the bin layers were too wet during loading. Starting with a temperature check, follow the preceding procedure and perform the Bin Corrective Action procedure as needed.

- **The compost facility is producing odors and drawing coyotes, flies, mice, and other pests.**

In general, odors are caused when the ingredients in the composting bin are out of balance. There may be too much or too little moisture, or too little carbon (bulking agent) in relation to nitrogen (carcasses, manure, effluent, fertilizer). Odors may also result from exposure of the carcasses to the outside air; they should be fully enclosed in bulking agent.

Insects and mice can only survive in a compost bin if it is not functioning properly; under normal circumstances, the extremely high temperatures in the bin (> 130 ^{0}F or higher) prevent infestation or bin rummaging by coyotes. The presence of these pests indicates that something has gone wrong with the process.

Solutions: Conduct the various tests detailed in Section 4, "Monitoring the Compost" and the procedures discussed above. These tests will provide data about the state of the compost and should reveal the source of the problem. If odor and pest problems persist, you may have to transfer the material into a new bin, per the Bin Corrective Action procedure. For each layer, ensure that no carcass lies directly against the wall of the bin; leave at least six inches of bulking agent between the edge of the bin and the nearest carcass.

Bin Corrective Action

If bin is too wet - odors or fluids are emanating from a bin:

1. Check the temperature charts. Compare temperature with depth. If the temperature is cold inside and warm outside, the bin may be too wet and its contents are getting too little or no oxygen, and has gone anaerobic. If the temperature profile is reversed then the bin is too dry and the odor is not from the material being too wet.
2. Dig into the bin from a few sites on top and from the front. Check for wetness and bad odors.
3. If the bin appears wet, use a bucket loader to take a large portion from the front of the bin. Collect some of the material for a hand squeeze moisture test and perhaps, if you have a microwave oven, do a microwave oven test. Also, check the odor and color of the material.
4. If the bin material is too wet, i.e., the oven test result is high, the material stinks and is brown and gooey, the inside of the pile is much cooler than the outside, and moisture is leaking from the bottom of the bin, then you must place a fresh layer of bulking agent into an unused secondary bin.
5. With the bucket loader, start the transfer of material from the primary to the secondary bin.
6. Use the bale buster to blow in straw, weeds, corn stalks, and/or grass or a bucket full of bulking agent when wet areas are observed. Do not add too much bulking agent or you will have to move the contents again in a couple of weeks while adding water and feedstock.
7. Take intermittent samples and run moisture assessments on them. Keep the moisture at or near 50% or two bounces of the squeeze ball if using the squeeze test.
8. Once all of the contents from the primary bin have been transferred to the secondary bin, immediately start the temperature monitoring protocol. Experience dictates temperatures will soon start to reach acceptable levels.

Obviously all of the layers will be mixed together after this process, however, as long as the moisture, carbon, nitrogen, and air levels are brought back into balance it does not matter; the material will start composting again. There is no exact way of fixing a wet bin but good observations and a little common sense go a long way.

If a bin is too dry, which will be indicated by cool temperatures on the outside and warm temperatures on the inside, rake back the bin cap and inject water using a 1 ¼ inch piece of PVC pipe fitted to a water hose. Cap the non-hose end and drill several holes in the bottom ⅓ of the PVC pipe. Push the pipe into the bin and turn on the water. Inject water at several locations the top of the bin while checking the moisture to ensure you do not over water the bin. Replace the bin cap.

Monitoring and correcting the bin for odor, temperature, and moisture on a daily or weekly basis will prevent the need for major corrective action and should ensure dark, humic rich, good looking compost that has a soil or dirt cellar like odor.

Swine Mortality
Bulk Density Analysis Log Sheet

Sampler: ______________________________________

Date: ______________________________________

BIN ID # ____________________________

Weight 1 ______________________ lb/cubic foot   Time 1 ____________________

Weight 2 ______________________ lb/cubic foot   Time 2 ____________________

Tare Weight of 1 cubic foot Box (if needed) ____________________ lb

Weight 1 - Tare Weight = ____________________ lb/cubic foot

Weight 2 - Tare Weight = ____________________ lb/cubic foot

(Weight 1 + Weight 2) / 2 = ____________________ lb/cubic foot Average BD

Average x 27 = ________________________ lb/cubic yard

Notes:

Addendum A

6. Use of a Vertical Grinder-Mixer in Mortality Composting

■ The Grinder-mixer

Using a vertical dairy-type grinder-mixer is a new and exciting method for preparation and mixing of mortalities and bulking agent prior to composting. Although using the grinder-mixer for mortality composting is still in its infancy the improved homogeneity of the grinder-mixer mix provides potential benefits over typical mortality bin composting including:

- reduces quantities of required bulking agent,
- decreases composting time,
- and decreases labor associated with mortality and bulking agent preparation.

The grinder exposes a larger surface area making it much easier for the bacteria to attack small pieces of carcass material mixed in with the bulking agent instead of trying to consume the entire animal surrounded by layers of bulking agent.. Bulking agent to mortality ratios have **yet** to be determined but initial studies show that as little as 1 ton of bulking agent to 4 to 6 tons of mortalities can be achieved. In typical bin composting, due to the animals size, the amounts can be reversed with as high as 4 tons of bulking agent to 1 ton of mortality depending on bulking agent type. Since the bulking agent usually has to be purchased, or at a minimum, prepared for composting, the savings can be substantial (see estimated cost savings example below).

Vertical grinder-mixers are common in the dairy industry where baled, liquid, and grain or pelleted type feeds are processed at one time, by one machine without leakage. The grinder-mixer is tub shaped - totally self-contained and has from one to two cone shaped vertical augers set in the bottom of the tub that are fitted with horizontal blades (photos show a double blade assembly) which pull material from the bottom of the tub (at 500 RPM) to the top in a volcano type action while cutting and mixing.

The vertical grinder-mixer works particularly well for mortality composting because, like dairy rations, the compost mix will be made up of solids and liquids that must be contained and properly distributed throughout the final mixture. The containment of body fluids from the mortalities is especially important for biosecurity and safety reasons. Also, no preliminary splaying is necessary.

When using a grinder, the steps described in Section 3A, "Preparing the Ingredients" page 12, are not necessary, the grinder will perform that function. Bulking agents such as straw, grass, weeds, non-woody yard waste, sawdust, wood shavings, and old alfalfa are also cut, sized, and/or mixed by the grinder-mixer. Woody materials such as tree branches, processed wood, and large yard waste will have to be sized prior to mixing as per the specifications noted in Section 3A, "Preparing the Bulking Agent" page 12.

The grinder-mixer makes mortalities no more difficult to compost than any other feedstock such as manure, green yard waste, or food waste. One person using the grinder-mixer and a bucket loader can handle the daily mortalities from start to finish in a couple of hours. The procedure for loading the grinder-mixer is also like using the grinder for feeding dairy cows. Usually, a weighing scale is installed as part of the grinder-mixer which allows the precise addition of materials to the unit. Prior to loading, the unit is engaged and brought up to working speed (500 RPM). Using a bucket loader the bulking agent is loaded into the unit, by weight, followed by the mortalities. Preliminary observations show that the mixture's moisture level can be adjusted by the amount of mortalities added instead of using bulking agent to mortality ratios and then adding water as described in Section 3B "Filling the Phase 1 Bins" page 15. Water may not have to be added during the mixing period if there are sufficient mortalities to provide the necessary moisture (60 to 70%). The moisture hand squeeze test can be used during the grinding-mixing phase to determine at what point to stop adding pigs, or other mortalities i.e. chicken or cattle see Section 4B "Testing for Moisture" page 18. Since using the grinder-mixer is relatively new to mortality composting, getting the mix "right" will be the first order of business but should be no more difficult than obtaining the "right" mix for manure, grass, bio-solids, or any other nitrogen rich material.

The processed material is discharged from the unit either by a built in side or back auger and/or elevator belts depending on the model used (see photo for example of a side discharge belt). Once the material has been discharged it must be treated like any other mortality compost mix. If the ***processed mixture*** is to be bin composted, refer to Section 3. "Filling the Bins" starting on page 11 and Section 4. "Monitoring the Process", starting on page 18. Use the same procedures for capping the bin, monitoring the temperatures, moving the composting material from the primary bin to the secondary bin, water additions, and corrective actions. They are all applicable; the only variation is that the mortalities are part of the mix rather than being surrounded by the mix. This homogenous mix allows for better bacteria contact with the materials and should reduce composting time as compared to regular bin composting. Any type of composting – windrow, Ag Bag, mound methods can be used with the processed mixture

The amount of reduction in composting time will depend on the usual factors such as C:N ratio, moisture, bulking agent type, and the compost management method. If the ground-mixed material were to be placed in a Phase 1 bin, the first heating could be completed within 30 to 60 days instead of the typical 90 days discussed throughout this manual. Phase 2 could also be completed in 30 to 60 days, thus the overall time period could be reduced from 180 days to 60 to 120 days. National Hog Farms in Kersey Colorado composted splayed swine carcasses in an active manure based windrow in 110 days total, there is no reason why that could not be replicated using the ground-mixed material from the grinder-mixer.

Using the grinder-mixer, mortality composting can become an efficient means of carcass disposal for Animal Feeding Operations (AFOs) in conjunction with EPA regulated manure management requirements signed into law by President Bush on December 16, 2002. As AFOs seek newly required permits they will find it is necessary to greatly reduce land application of raw manures. Composting will become a viable part of this reduction. The grinder-mixer allows the operator to integrate mortalities into conventional manure composting more easily than if straight bin composting is used. Manures can be mixed with the mortalities to offset some of the bulking agent and /or mortalities can be mixed into manure composting processes. Freshness and purity of the manure are critical (dirt in manure added to a compost bin is a kiss of death to thermophilic bacteria) so only fresh manures low in feedlot dirt should be used.

■ Cost Comparison

The following is a cost estimate for Bin Mortality Composting for a large “idealized” 70,000 sow farrow-to-finish operation This example is for reference only and should not be used in estimating costs without analyzing, in-depth, each operation’s mortality rates (mortality rate formulation information can be found on page 10 of this manual). The example operation could produce 1,750,000 pigs per year. Without distinguishing between pig size and associated death rates this operation could loose up to 8,600 pounds of mortalities per day or 60,200 pounds/week. Using the less than conservative 1.5:1 bulking agent /mortality ratio (by weight ratios are difficult because of vastly varying bulking agent densities and the initial ratio could easily be as high as 4:1 bulking agent/mortality) and sizing the bins to fill weekly, this operation would need 18 primary bins 7 feet high x 12 feet deep x 60 feet wide. The bins would use over 91,000 pounds of straw and use 720 square-feet of space per week.

Typically, a bin-based operation requires 1 secondary bin (rotation bin) for each primary bin so there would be 36 bins total or over 25,000 square-feet of space just for the bins. This example is based on straw as the primary source of bulking agent. If each bale were to weigh 1,500 pounds the operation would need over 60 bales per week or 3,120 bales per year. At $35.00/bale it would cost over $109,000 per year for bulking agent. Other costs include land, water, active site management and bin monitoring, personnel, bin building, bulking agent and mortality preparation, equipment (bucket loaders, dump trucks, grinders), bin loading, and moving material between bins.

In the above example using a grinder before bin composting could save $81,750 to $90,300 due to reduced bulking agent costs. This savings would more than cover the cost of a $40,000 to $60,000 grinder. Even though there has not been rigorous testing during the grinder-mixer process as of yet, observation coupled with common sense and composting experience indicate this method has promise of becoming a safe, proven method.

Resources

Air Quality Regulation: www.cdphe.state.co.us/regs/100104.pdf

Water Quality Regulation: www.cdphe.state.co.us/regs/100261.pdf Part 13 applies to Hog Farms

Confined Animal Feeding Operation Regulation: www.cdphe.state.co.us/regs/100281.pdf

Barton, Lionel T., and Raymond C.Benz. Composting poultry carcasses. In MP317, Cooperative Extension Service, University of Kansas.

BioCycle: Journal of Waste Recycling. January 1994, p.51 (formerly Compost Science and Compost Science/Land Utilization). Published monthly by The JG Press, Inc.

Buchanan, M., and S.Gleissman.1991. How compost fertilization affects soil and crop yield. Biocycle, December:72-77.

Donald, James O., and John P. Blake.1992. Dead poultry composter construction. In Poultry By-Product Management, Auburn University, Alabama Cooperative Extension Service.

Epstein, 1997. The Science of Composting,

Fulhage, C. 1994. Composting Dead Swine. WQ 225. University of Missouri Corporate Extension publication WQ22, University of Missouri, Columbia, Missouri.

Golueke, Clarence G. 1991. Principles of composting. In The BioCycle Guide to the Art and Science of Composting, Jerome Goldstein, ed., The JG Press, Inc., Emmaus, pp.13-40.

Haug, Roger T. The Practical Handbook of Compost Engineering, 1993

Haug, Roger T. 1986. Composting process design criteria. BioCycle 27:53-57.

Haug, Roger T. 1990. An essay on the elements of odor management. BioCycle October: 60-67.

Henry, S. T. 1995. Composting – An innovation in dead swine disposal. ASAE Paper No.954506. Presented at the ASAE International Meeting, Chicago IL. ASAE, St. Joseph, MI.

Laliberty, Lucien. 1987. Composting for a Cash Crop. In On-Farm Composting Conference in U. of Massachusetts.

Langston, John, Carman, Dennis, VanDevender, Dr. Karl, and Boles, Jack, Jr. Disposal of Swine Carcasses In Arkansas.1997. COOPERATIVE EXTENSION SERVICE, University of Arkansas, United States Department of Agriculture and County Governments Cooperating .

Martin, A. M., J.Evans, D.Porter, and T. R. Patel.1993. Comparative effects of peat and sawdust employed as bulking agents in composting. Bioresource Technology 44:65-69.

Mescher, Terry, Wolfe, Ken, Stowell, Rick and Kenner, Harold. 1999. Swine Composting Site Selection. Ohio State University Fact Sheet.

The Midwest Plan Services, 1993. Livestock Waste Facilities Handbook

Person, Howard L., and Walid H. Shayva.1993. A composting process design computer model. American Society of Agricultural Engineers Paper, St. Joseph, MI.

Rymshaw, Ellen, Michael Walter, and Thomas Richard. 1992. Agricultural composting: environmental monitoring and management practices. In On Farm Composting Handbook, ch. 6, Management, Robert Rynk, ed., Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Rynk, Robert, et al. 1992. On-farm Composting Handbook (NARES-54) Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Simpson, Michael. Economics of agricultural composting.

USDA, Natural Resources Conservation Service, 2000. Part 637 Environmental Engineering National Engineering Handbook, Ch. 2 Composting. USDA NRCS, Washington, D.C.

Walters, 1993. Fletcher Sims' Compost

Wistreich, George A., and Max D. Lechtman. 1988. Microbiology. 5th ed., MacMillan Publishing Co., New York.

QUICK START GUIDE

THE COMPOSTING TIMELINE

	Duration	Ingredients	Steps	Outcome
Phase 1	~ 12 weeks	Hog carcasses, bulking agent, water Common bulking agents: sawdust, cornstalks, straw, crop wastes 4 to 1 ratio between bulking agent and hog carcass	1. Build composting bins 2. Load ingredients into bins, layer by layer 3. Perform regular tests to monitor composting process	Soft tissue decomposes Bones soften and partially decompose
Phase 2	8 – 12 weeks	Phase 1 compost and water	1. Transfer Phase 1 compost into new bins 2. Add moisture 3. Remove finished compost	Bones break down fully Compost turns dark brown to black and acquires a musty odor

EQUIPMENT CHART

Job	Used for	Equipment
Hauling Material (based on operation size)	Moving carcasses and bulking agent to the composting site Loading carcasses and bulking agent into the bins Transferring compost from Phase 1 bins to Phase 2 bins Transferring finished compost from Phase 2 bins to storage area	Backhoe, tractor, or skid loader outfitted with 1¼- to 4-yard bucket
Bulking Agent Preparation	Grinding corn stalks, hay, straw, grass, or other material used as bulking agent	Wood chipper, bale processor, grinder
Hauling "deads"	Hauling and sorting carcasses	Pickups fitted with Tommy Lifts, dump trucks and farm trucks used with a loader
Hauling water	Adding moisture to compost bins	Tanker trucks, honey wagons, pumper trucks, onsite water
Hauling manure	Adding effluent and or manure to compost bins	Honey wagon with pump, side discharge manure trucks, loader
Log book	Record the date each bin is filled Record results of compost monitoring tests (see part 4, "Monitoring the Compost") Record temperatures in Temperature Monitoring Sheet	See Bin Temperature Monitoring Sheet. Section 4 (Monitoring Compost Section)

SITE SELECTION CHECKLIST

Composting site must be:

- ❑ Away from ponding areas or drainage patterns
- ❑ At least 300 feet from streams, lakes, waterways

Location must provide

- ❑ Suitable access to storage for bulking agent
- ❑ Clearance from underground and overhead utilities
- ❑ Minimal interference with other farm traffic
- ❑ Sufficient square footage for your volume of carcasses

Site must have

- ❑ Runoff collection and available treatment areas
- ❑ All-weather access to the compost area
- ❑ All-weather compost pad

CONSTRUCTING COMPOSTING BINS

1. Two sets of bins: Phase 1 bins, Phase 2 bins
2. Commonly built of hay, wood, concrete, tire bales
3. Should be built upon impervious pad to prevent leaching
4. Bins should be three-sided, with walls at least 6 feet high and surface area of 150-200 square feet
5. Provide 150 cubic feet of bin capacity per 1,000 pounds of hog carcasses

FILLING THE BINS

1. Fill bins in alternating layers of hog carcass and bulking agent
2. Bottom layer: bulking agent only, 12-18 inches deep
3. 1st carcass layer: place carcasses in bin stomach up; carcasses > 100 pounds should be splayed
4. Allow 3-12 inches between carcasses; fill intervals with bulking agent
5. Add water to layer
6. Cover carcass layer with layer of bulking agent
7. Repeat for each successive layer
8. When bin is full, build cap out of dense bulking agent, sloping from north to south, to divert rainwater
9. Record date of capping in log book

MONITORING COMPOST

For details on test procedures, see part 4, "Monitoring Compost"

TROUBLESHOOTING

For details on troubleshooting, see part 5, "Troubleshooting"